

What is claimed is:

- 1 1. A memory device comprising:
2 a substrate; and
3 a single transistor formed on the substrate, the transistor having a
4 gate with a nonvolatile memory element.
- 1 2. The memory device of claim 1, wherein the nonvolatile memory
2 element is formed between a gate insulating layer and a gate conductive
3 layer, both layers constituting the gate.
- 1 3. The memory device of claim 1, wherein the nonvolatile memory
2 element is connected to first and second bit lines separated from each other.
- 1 4. The memory device of claim 3, wherein the first and second bit
2 lines pass below the nonvolatile memory element.
- 1 5. The memory device of claim 3, wherein the first and second bit
2 lines pass above the nonvolatile memory element.
- 1 6. The memory device of claim 1, wherein the nonvolatile memory
2 element includes:
3 semiconductor quantum dots formed on the gate insulating layer; and
4 an amorphous material layer covering the plurality of semiconductor
5 quantum dots, wherein the amorphous material layer stores carriers emitted
6 from the semiconductor quantum dots and maintains the carriers in a
7 nonvolatile state until the emitted carriers are recaptured into the
8 semiconductor quantum dots.
- 1 7. The memory device of claim 6, wherein the semiconductor
2 quantum dots are silicon dots arranged at regular intervals.

1 8. The memory device of claim 6, wherein the amorphous
2 material layer, which is an amorphous dielectric layer, is an amorphous
3 silicon nitride layer, an amorphous alumina layer or a silicon oxide layer
4 (SiO_2).

1 9. The memory device of claim 2, wherein the nonvolatile memory
2 element includes:

3 semiconductor quantum dots formed on the gate insulating layer; and
4 an amorphous material layer covering the plurality of semiconductor
5 quantum dots, wherein the amorphous material layer stores carriers emitted
6 from the semiconductor quantum dots and maintains the carriers in a
7 nonvolatile state until the emitted carriers are recaptured into the
8 semiconductor quantum dots.

1 10. The memory device of claim 9, wherein the semiconductor
2 quantum dots are silicon dots arranged at regular intervals.

1 11. The memory device of claim 9, wherein the amorphous
2 material layer, which is an amorphous dielectric layer, is an amorphous
3 silicon nitride layer, an amorphous alumina layer or a silicon oxide layer
4 (SiO_2).

1 12. The memory device of claim 3, wherein the nonvolatile
2 memory element includes:

3 semiconductor quantum dots formed on the gate insulating layer; and
4 an amorphous material layer covering the plurality of semiconductor
5 quantum dots, wherein the amorphous material layer stores carriers emitted
6 from the semiconductor quantum dots and maintains the carriers in a
7 nonvolatile state until the emitted carriers are recaptured into the
8 semiconductor quantum dots.

1 13. The memory device of claim 12, wherein the semiconductor
2 quantum dots are silicon dots arranged at regular intervals.

1 14. The memory device of claim 12, wherein the amorphous
2 material layer, which is an amorphous dielectric layer, is an amorphous
3 silicon nitride layer, an amorphous alumina layer or a silicon oxide
4 layer(SiO₂).

1 15. The memory device of claim 4, wherein the nonvolatile memory
2 element includes:

3 semiconductor quantum dots formed on the gate insulating layer; and
4 an amorphous material layer covering the plurality of semiconductor
5 quantum dots, wherein the amorphous material layer stores carriers emitted
6 from the semiconductor quantum dots and maintains the carriers in a
7 nonvolatile state until the emitted carriers are recaptured into the
8 semiconductor quantum dots.

1 16. The memory device of claim 15, wherein the semiconductor
2 quantum dots are silicon dots arranged at regular intervals.

1 17. The memory device of claim 15, wherein the amorphous
2 material layer, which is an amorphous dielectric layer, is an amorphous
3 silicon nitride layer, an amorphous alumina layer or a silicon oxide layer
4 (SiO₂).

1 18. The memory device of claim 5, wherein the nonvolatile memory
2 element includes:

3 semiconductor quantum dots formed on the gate insulating layer; and
4 an amorphous material layer covering the plurality of semiconductor
5 quantum dots, wherein the amorphous material layer stores carriers emitted
6 from the semiconductor quantum dots and maintains the carriers in a
7 nonvolatile state until the emitted carriers are recaptured into the
8 semiconductor quantum dots.

1 19. The memory device of claim 18, wherein the semiconductor
2 quantum dots are silicon dots arranged at regular intervals.

1 20. The memory device of claim 18, wherein the amorphous
2 material layer, which is an amorphous dielectric layer, is an amorphous
3 silicon nitride layer, an amorphous alumina layer or a silicon oxide layer
4 (SiO₂).

1 21. The memory device of claim 4, wherein the first and second bit
2 lines are conductive impurity layers formed from the surface of the substrate
3 to a predetermined depth.

1 22. The memory device of claims 3, wherein a sense amplifier is
2 connected to the first bit line as a current measuring means.

1 23. The memory device of claim 4, wherein a sense amplifier is
2 connected to the first bit line as a current measuring means.

1 24. The memory device of claim 5, wherein a sense amplifier is
2 connected to the first bit line as a current measuring means.

1 25. The memory device of claim 21, wherein a sense amplifier is
2 connected to the first bit line as a current measuring means.

1 26. A semiconductor memory device comprising:
2 a substrate;
3 a transistor formed on the substrate; and
4 a nonvolatile memory means formed between the transistor and the
5 substrate.

1 27. The semiconductor memory device of claim 26, wherein the
2 nonvolatile memory means includes an amorphous material layer formed on
3 the substrate and semiconductor quantum dots formed on the amorphous
4 material layer, wherein the amorphous material layer stores carriers emitted
5 from the semiconductor quantum dots and maintains the carriers in a

6 nonvolatile state until the emitted carriers are recaptured into the
7 semiconductor quantum dots.

1 28. The semiconductor memory device of claim 27, wherein the
2 transistor comprises:

3 first and second metal layer patterns formed on the amorphous
4 material layer, both being separated from each other;

5 an insulating layer formed on the amorphous material layer so as to
6 cover the semiconductor quantum dots and the first and second metal
7 layers;

8 and a word line formed on the insulating layer at a position
9 corresponding to a position where the semiconductor quantum dots are
10 formed.

1 29. The semiconductor memory device of claim 27, wherein the
2 semiconductor quantum dots are a plurality of spaced silicon dots.

1 30. The semiconductor memory device of claim 27, wherein the
2 amorphous material layer, which is an amorphous dielectric layer, is an
3 amorphous silicon nitride layer, an amorphous alumina layer or a silicon
4 oxide layer (SiO₂).

1 31. The semiconductor memory device of claim 28, wherein the
2 semiconductor quantum dots are a plurality of spaced silicon dots.

1 32. The semiconductor memory device of claim 28, further
2 comprising:

3 an interlayer dielectric layer formed on the insulating layer for
4 covering the word line;

5 a via hole formed in the interlayer dielectric layer and the insulating
6 layer so that the first metal pattern is exposed; and

7 a fourth metal layer pattern formed on the interlayer dielectric layer for
8 filling the via hole and passing across the word line.

1 33. A method for operating a memory device including a single
2 transistor formed on a substrate, wherein the single transistor is a memory
3 transistor having a gate with a nonvolatile memory element, and the
4 nonvolatile memory element is connected to a bit line comprised of first and
5 second bit lines passing across the gate, wherein an addressing voltage and
6 a write voltage are applied to the gate and the bit line, respectively, to write
7 data to the nonvolatile memory element.

1 34. The method of claim 33, wherein first and second write
2 voltages are applied to the first and second bit lines, respectively, to store
3 data "1" and "0" to the nonvolatile memory element, and the first and second
4 write voltages are the same as or different from each other.

1 35. The method of claim 33, wherein a second write voltage is
2 applied to the first bit line to store data "1", a first write voltage is applied
3 to the second bit line to store data "0", and the first and second write
4 voltages are the same as or different from each other.

1 36. The method of claim 33, wherein a first write voltage is applied
2 to the second bit line to store data, and a second write voltage higher than
3 the first write voltage is applied to the second bit line to store different data.

1 37. The method of claim 33, wherein the written data is read by
2 measuring the conductivity of the nonvolatile memory element.

1 38. The method of claim 37, wherein an addressing voltage is
2 applied to the gate, and then a current measuring means is connected to the
3 first bit line to measure current between the gate and the first bit line and
4 thus the conductivity of the nonvolatile memory element.

1 39. The method of claim 38, wherein data "1" or data "0" is read
2 depending on the measured current.

1 40. A method for operating a memory device including a substrate,
2 a transistor formed on the substrate, the transistor having a gate, a drain
3 connected to a bit line, and a source connected to a source of another
4 transistor, a nonvolatile memory element formed between the gate and the
5 substrate, and a metal line parallel to a word line connected to the transistor,
6 wherein data is written by changing the conductivity of the nonvolatile
7 memory element when the metal line is grounded.

1 41. The method of claim 40, wherein the nonvolatile memory
2 element is comprised of a material layer for storing carriers, and
3 semiconductor quantum dots formed thereon.

1 42. The method of claim 41, wherein a write voltage and an
2 addressing voltage are applied to the bit line and the word line, respectively,
3 when the metal line is grounded, to write data by changing the conductivity
4 of the carrier storing material layer.

1 43. The method of claim 42, wherein data is written by changing
2 the addressing voltage while the write voltage remains constant.

1 44. The method of claim 42, wherein data is written by changing
2 the write voltage while the addressing voltage remains constant.

1 45. The method of claim 40, wherein the written data is read by
2 measuring the conductivity of the nonvolatile memory element.

1 46. The method of claim 45, wherein a read voltage is applied to
2 the bit line, and then a current measuring means is connected to the metal
3 line to measure current between the bit line and the metal line and thus the
4 conductivity of the nonvolatile memory element.

1 47. The method of claim 46, wherein a different first or second
2 read voltage is applied to the bit line to measure current between the bit line
3 and the metal line and thus read data.

1 48. The method of claim 45, wherein a read voltage and an
2 addressing voltage are applied to the metal line and the word line,
3 respectively, and then a current measuring means is connected to the bit line
4 to measure current between the metal line and the bit line and thus the
5 conductivity of the nonvolatile memory element.

1 49. The method of claim 47, wherein data "0" is read when
2 the measured current is large and the data "1" is read when the measured
3 current is small.

1 50. The method of claim 48, wherein data "0" is read when
2 the measured current is large and the data "1" is read when the measured
3 current is small.

1 51. A method of manufacturing a memory device comprising:
2 defining a field region and an active region in a substrate;
3 forming a field oxide layer on the field region;
4 forming an insulating layer on the active region;
5 patterning the insulating layer to form first and second bit lines
6 separated from and parallel to each other on the active region;
7 forming a memory element for storing data in a nonvolatile state on
8 the insulating layer and the first and second bit lines so that the memory
9 element passes across the first and second bit lines; and
10 forming a word line on the insulating layer and the memory element.

1 52. The method of claim 51, wherein the step of forming the
2 memory element further comprises:
3 forming a plurality of spaced semiconductor quantum layers on the
4 insulating layer and the first and second bit lines; and

5 forming an amorphous material layer covering the semiconductor
6 quantum dots on the insulating layer.

1 53. The method of claim 51, wherein the step of forming the
2 memory element comprises:
3 forming an amorphous material layer on the insulating layer and the first
4 and second bit lines; and
5 forming spaced semiconductor quantum dots on the amorphous
6 material layer.

1 54. The method of claim 52, wherein the amorphous material layer
2 is an amorphous dielectric layer.

1 55. The method of claim 54, wherein the amorphous dielectric
2 layer is formed of an amorphous silicon nitride layer, an amorphous alumina
3 layer or a silicon oxide layer (SiO₂).

1 56. The method of claim 53, wherein the amorphous material layer
2 is an amorphous dielectric layer.

1 57. The method of claim 56, wherein the amorphous dielectric
2 layer is formed of an amorphous silicon nitride layer, an amorphous alumina
3 layer or a silicon oxide layer (SiO₂).

1 58. The method of claim 52, wherein the semiconductor quantum
2 dots are silicon dots for emitting carriers to the amorphous material layer or
3 recapturing the emitted carriers by application of a voltage.

1 59. The method of claim 53, wherein the semiconductor quantum
2 dots are silicon dots for emitting carriers to the amorphous material layer or
3 recapturing the emitted carriers by application of a voltage.

1 60. A method of manufacturing a memory device, the method
2 comprising:
3 forming a nonvolatile amorphous material layer on a substrate; and
4 forming a transistor on the nonvolatile amorphous material layer so
5 that semiconductor quantum dots for emitting carriers to the amorphous
6 material layer or recapturing the emitted carriers by application of a voltage
7 are formed between the transistor and the amorphous material layer.

1 61. The method of claim 60, wherein the step of forming the
2 transistor comprises:
3 forming first and second metal layer patterns on the nonvolatile
4 amorphous material layer;
5 forming semiconductor quantum dots on the nonvolatile amorphous
6 material layer between the first and second metal layer patterns;
7 forming a gate insulating layer covering the resultant in which the
8 semiconductor quantum dots are formed on the substrate; and
9 forming a word line corresponding to the semiconductor quantum dots
10 on the gate insulating layer.

1 62. The method of claim 60, wherein the nonvolatile amorphous
2 material layer is formed of an amorphous silicon nitride layer, an amorphous
3 alumina layer or a silicon oxide layer (SiO_2).

1 63. The method of claim 60, wherein the semiconductor quantum
2 dots are silicon dots.

1 64. The method of claim 61, further comprising:
2 forming an interlayer dielectric layer covering the word line on the
3 gate insulating layer;
4 forming a via hole for exposing the first metal layer pattern; and
5 forming a fourth metal layer pattern for filling the via hole and passing
6 across the word line on the interlayer dielectric layer.